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A Study of Whiteness Retention of Selected White Fabrics Using Hard and Softened Water with Various Laundry Products

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A STUDY OF WHITENESS RETENTION OF SELECTED WHITE FABRICS USING HARD AND SOFTENED WATER WITH VARIOUS LAUNDRY PRODUCTS

BY

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

The introduction of man-made fibers into the textile field has been revolutionary. However, these fibers are coming to be an accepted part of the textile industry (17). "Miracle" fibers, as they were first publicized, were not perfect textiles, as the consumer soon discovered (20)(10). There were advantages and disadvantages in the use of these new synthetic textiles as there had been with the natural fibers. Years of experience with the natural fibers had established certain basic procedures for their laundering. The new fibers introduced new problems and required new procedures.

Modern laundry products and appliances have made wash day easier for the homemaker. However, the new developments in carefree textiles have added problems that are new and unique. Laundry workers in their research do not all agree as to which is the best way to obtain a clean wash. The common procedure seems to be to follow the laundering directions of the manufacturer of the textile article or of the laundry equipment. There have been increasing complaints of discoloration however, especially of the white fabrics.

Hunter (13) defines a white surface as one which appears white when seen in its normal surroundings. This definition then explains why all white fabrics may appear to be white until compared to another "white" fabric. It has been found that most white materials are naturally yellowish. Even after finishing with bluish dyes or pigments, the white materials encountered in everyday life are most likely to be yellowish or bluish (13).

Retention of original brightness of a fabric is the purpose of laundering. Usually white fabrics are the standard that the homemaker uses to judge whether her wash is clean and whether her products, equipment and techniques are producing the brightest washes possible. White must stay white to remain acceptable. When a fabric loses its whiteness the color usually changes to yellow, and in exceptional cases to brown or grey (22).

Through reports of laundry studies it has been found that discoloration is usually caused by:

1. The use of inefficient laundry methods that did not remove soil completely.
2. Soap deposits on garments washed in hard water without a water softener.
3. Dye transfer to white fabrics during the laundering of white fabrics with colored articles.
4. Use of excessive heat during drying and/or ironing. (11)(22)(36)

With these facts in mind, and considering the physical and chemical properties of their textiles, the manufacturers of the man-made fibers have made specific laundering recommendations for their products. They recommend that the articles made of their fibers:

1. Be washed thoroughly after each wearing.
2. Be thoroughly rinsed to remove all soap or detergent from the fabric.
3. That white articles be washed only with other white articles.
4. That warm water be used and low or medium temperature settings for drying and/or ironing (3)(5)(16)(25)(28)(30).

Complete satisfaction by consumers has not been obtained from the use of these recommendations. This study has been made to investigate a specific area of the problem of discoloration. The question has arisen, do white fabrics of synthetic fibers discolor with washing when there is an absence of soil?

The object of this research then was to determine if white fabrics, especially those man-made fibers that have caused consumer dissatisfaction, would discolor when the recommended laundry practices were followed and soil was not involved. As a second objective, several combinations of washing products were used to determine if any combination produced whiter results in any of the fabrics used in the experimental washings.

REVIEW OF LITERATURE

Laundry research of man-made fibers has a history of only a dozen years or so and has not been developed broadly. Much of the work with these fibers has been with the characteristics for which they are noted, mainly, easy care and improved wearability, rather than soil retention and/or removal (21)(23). Fabrics of Dacron, nylon, cotton and a blend of 65 per cent Dacron and 35 per cent cotton were selected for this study and it was of these fibers that a background study was made.

The Consumers Report (26), in 1951, published their findings that Orlon and Fiber V (Dacron) shirts were easy to wash and resisted staining but also said there was no evidence of resistance to soil.

In 1954 a report was published on the soiling of fabrics in contact with the skin (35), in which test collars were used. The collars were made of materials composed of cotton and synthetic fibers. This report indicated that Dacron soiled more rapidly than cotton and the authors suggested that oily soils actually dissolve within the fiber such as a disperse dye does in acetate. These workers found dry cleaning solvents appeared to be most effective in removing oily soils from hydrophobic fibers.

Margaret S. Furry (6) in her research with home laundry detergents in 1956 found that the amount of soil can be a guide in determining the amount of detergent needed for fabrics of cotton, linen and man-made fibers. The fabrics she used were made of Acrilan, Dacron, Dynel, nylon and Orlon, and showed no significant change in whiteness due to repeated washing with any of the soap or synthetic detergents. No details were given on the laboratory procedure used but the recommendations were proposed for conventional and automatic washing machines.

A home study of a shirt of Dacron-cotton blend was undertaken by a homemaker and her husband in order to determine the best shirt fabric for an extended trip (31). This shirt was worn every day for 100 days. It was washed by hand at the end of each day according to directions from the shirt manufacturer. They found that it yellowed after 75 washings and did not change appreciably thereafter. Their experimental procedure was not carefully regulated but would represent a typical handling of a home, hand washed garment.

A comparison of Dacron and cotton blends with all-cotton fabrics was made by Hawkins and Keeney (10) in 1956. One of the advantages of the Dacron and cotton blend they used was the maintenance of original appearance and texture after repeated laundering. This research was a laboratory experiment and was followed by a wear study and reported by Keeney in 1957 (18).

In this latter study, Keeney found that nine out of ten of the wearers of her experimental shirts preferred the cotton garments. Other information gained by wearing was that the blended fabric was uncomfortably warm, static electricity was present, and the changes in original color and the retention of soil did not support the claims for comfort and attractive appearance made by manufacturers of these garments. The soiled areas, spots and stains all needed careful attention. Bleaches or whitening agents were needed to prevent discoloration or yellowing.

When the synthetic fabrics were introduced it was noted that the smooth synthetic fibers gave the dirt particles practically no hold, whereas the shape of the cotton fiber was such that dirt would cling to it. It was reasoned that the lightest washing would be sufficient to get the synthetic materials clean.

O. Viertel (38), in a study of laundering Perlon and nylon stockings in 1957, states:

> This is not, however, the case, for washing is not as easy as that.....The dirt mixed with human fat is not removed with cold water alone. Such articles should be washed in lukewarm water with the addition of a gentle cleaner. Also, textiles made from synthetic fibers should not be worn too long or allowed to get too dirty before washing.[1]

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[1]Viertel, O. "Laundering of Textiles Made of Manmade Fibers," American Dyestuff Reporter 46:225 (1957).

His conclusion was that articles of clothing made of synthetic fibers that come in contact with the skin and are exposed to heavy soiling are best washed at 60-70° C. (no higher). A regular commercial detergent gives the best results with white articles without having to rub excessively.

Galbraith (8) reported on the cleaning efficiency of home laundering detergents in 1960. Before this time most of the research of laundering products had been with cottons, but she included viscose rayon, wool, nylon, Orlon and Dacron in her experimental materials. She found that both temperature and softness of the water and the concentration of the soap or syndet were more important factors in cleaning efficiency than brand or type of laundry product.

> In these tests the soaps were superior to the syndets in their prevention of graying of all fibers except cotton. And this superiority was most pronounced on wool, Dacron and nylon, the three fibers which exhibited the greatest tendency toward graying.[2]

Other information concerning washing procedures obtained from Galbraith's study was that washing temperature is still an important factor in determining the amount of soil removed. It was also true for all types of detergents even those sold as cold-water detergents. Washing at 120°F. will remove more soil than washing at lower temperatures.

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[2]Galbraith, Ruth Legg, "Cleaning Efficiency of Home Laundering Detergents," Journal of Home Economics 52:353 (1960).

An optimum concentration of detergent was 0.2 per cent for soft water and 0.3 per cent for hard water. She found that hard water should be softened for synthetic detergents also, because even increasing the amount of detergent in hard water did not improve the cleaning ability.

Furry, Bensing and Johnson (7) investigated the color effects produced on white fabrics by household detergents in 1961. They found that detergents with color pigments in their makeup had a graying effect on the cotton and some influence on the nylon-Dacron-cotton blended fabric but practically no effect on the final colors of the nylon, Dacron or the Dacron-cotton blend that was studied. Fluorescent whiteners included in the detergents masked some of the yellowness of the nylon fabrics but had little effect on the Dacron fabrics.

A wear study conducted by Gibson and Moore (9) in 1961, used blouses of fabrics composed of cotton, Dacron and a Dacron-cotton blend. They compared laundering and wearing qualities of these fabrics, with soil removal included as one of these qualities. They found cotton was superior to both Dacron and the blend with respect to whiteness retention, comfort, pilling and soil removal. Cotton was the first preference of the ten girls wearing the blouses, with the blended fabric second preference and the Dacron last. Gibson and Moore concluded that:

> This may be an indication that the average consumer considers comfort, appearance and soil removal more important than the necessity of ironing in wash and wear fabrics, at least these consumers seemed to have such a preference.[3]

A report of work that seems to apply to the problem of discoloration was made by Poole, Ross and Taube (27) for the United States Department of Agriculture and reported in January, 1962. The work was developed to study the use of modern home laundry equipment. They found both 100° and 60° F. were satisfactory water temperatures according to measurements of grayness, yellowness and calculated whiteness retention. These same measurements indicated that the synthetic detergent they used was not as effective as the soap in removing soil. The fluorescent whitener in the syndet tended to give better results in covering yellowness than did the soap. Cotton and blends with cotton had lower whiteness factors after gas tumble drying than those tumble dried by electricity or rack dried. According to the wearers, satisfactory cleanliness was maintained in all fabrics throughout all seventeen wash and wear periods. However, the original color measurements of some fabrics were not maintained, therefore they could not be considered clean.

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[3] Gibson, Clara Louise and Mae Y. Moore, "Wear Study of Wash and Wear Fabrics," Journal of Home Economics 53: 118-9 (1961).

These were studies that seemed to give some background to the question to be investigated. Change in color was found when the fabrics had been worn, and certain washing procedures were found to be more efficient than others in retaining whiteness and to remove soil (37). Using these findings as a guide the experimental procedures were set up for the study of whiteness retention of fabrics laundered in the absence of soil and using techniques simulating hand washing.

MATERIALS AND METHODS

Fabric Selection

The first consideration of this investigation was the materials to be studied. The fabrics were to be white or as nearly white as possible. A check of local stores and mail order catalogues revealed that items offered for sale were made of white cotton, Dacron, rayon, acetate, Orlon, Arnel, Dynel and nylon, as well as blends of these fibers. These fabrics were found in yardage and in such garments as uniforms, blouses, shirts and underclothing. The four fabrics chosen for this investigation were composed of cotton, Dacron, nylon and a Dacron-cotton blend of 65 per cent Dacron and 35 per cent cotton. These fabrics were chosen because:

1. Cotton could serve as a control. Its long use as a textile fiber has supplied a definite knowledge of its properties and washing requirements.
2. The fibers chosen were those fibers that could be laundered and dried under similar conditions so as to limit the number of variables.
3. The synthetic fibers are also the ones that have been on the market for a number of years and are the fibers that are responsible for many of the consumer complaints. (11)(12)(19)(24)(39)

There were no special instructions given for laundering or any information designating any special finishes or treatments that might have been given these fabrics, so it was assumed that there were none.

Fabric Sampling

All of the samples were a plain weave. The cotton and the Dacron-cotton blend were broadcloth and the Dacron and the nylon tafetta. Thirteen yards of each fabric were purchased and divided into nine samples. Eight of these samples were laundered. The ninth section was retained for laboratory analysis of original fabric. All fabrics were 44 inches wide. The selvedges were left intact and the cut edges of the samples were hemmed to prevent fraying. White thread was also used to sew an identifying code into each sample. Four of the samples were considered as replicate A and the other four were given identical treatment and labeled as replicate B.

Experimental Procedure

An experimental washing procedure was set up which would duplicate hand washing and yet could be replicated so as to obtain uniform results. The reason for the selection of this type of procedure was twofold. Manufacturers suggestions and research results indicate that when laundering fabrics of synthetic fibers, machine washing will produce whiter results than hand washing. However, hand washing is sometimes necessary for garments with delicate construction and trimming. White nylon and Dacron should be washed frequently and carefully and many users of the fabrics of these fibers do not have washing machines.

In order to obtain an even handling of the fabrics and yet have it done gently enough to resemble hand washing, a portable washing machine with a capacity of 4 gallons was selected. This machine was filled with the same amount of water for each washing and for the three rinses. The temperature of the water was measured, the washing products added and agitated for 1 minute. Four fabric lengths were then put into the water. The machine was run for 5 minutes. The rinsing periods were 2 minutes each in water of the same degree of hardness as had been used for the washing.

The water used was obtained from the city water supply and tested for hardness before each experimental washing. The water as it flowed from the tap was hard and varied from 18-20 grains per gallon of hardness during the period of experimental procedure. The softened water used was tap water passed through a home water softener of the ion exchange type. A constant check was made to keep the grains of hardness of the softened water to less than 3 grains per gallon. The experimental plan required the use of soap in the hard water therefore a water softener, sodium hexametaphosphate, was used with the soap in this washing treatment.

The iron content of the hard and sotened water was read at 0.15 and 0.14 parts per million respectively.

A temperature of 120° F. ± 2° F. was used for the washing and 100° F. ± 2° F. for the rinsing.

Unbuilt syndet and soap of a type recommended for fine fabrics and hand washing were seleced. White products were chosen so that color would not be a factor. The washing products were observed under the ultra-violet light prior to their use and they both contained a fluorescent whitener.

The liquid detergent and the granulated soap were commercial products available at the market to homemakers. A 0.03 per cent solution was used for both syndet and soap in the hard and softened waters. This measurement was recommended for hard water by Galbraith (8) and was used for both waters in this work to maintain uniformity in the experiment. For the amount of softener, the manufacturer's recommendations were followed.

Four different combinations of treatments were set up to be used on these samples. The two replicates were washed in 1) hard water and syndet; 2) hard water, soap and softener; 3) softened water and syndet and 4) softened water and soap.

After the washing and three rinsings, the moisture was allowed to drip from the fabrics. The samples were then placed in a gas fired drier and dried at a medium heat setting for 20 minutes (33). Four cotton dish towels were dried with the samples to make a larger load for more efficient drying and to absorb some of the excess moisture. Upon removal from the drier the samples were smoothed and folded on a flat surfact. Between washings samples were stored in a box lined with a white cotton sheet to keep fabrics protected from soil. No ironing or pressing was used.

There were 32 samples in the experimental work, divided into eight sets of washings. Each set of four samples were washed 30 times.

Laboratory Measurements

The physical measurements were conducted under standard atmospheric conditions (65 per cent relative humidity and 70° F.; ± 2 per cent or 2° F., respectively). Thickness, weight, yarn number and fabric strength and elongation were measured. These measurements were made to determine physical properties of each fabric and to show what relationship there might be between these four fabrics.

Procedures for the measurements of these properties are standard methods (1)(2).

Fabric Count

Fabric count was made on the four fabrics at two different positions on the original yardage. The number of warp and filling yarns in one inch was determined with a thread counting micrometer. The mean of the measurements in each direction is reported as fabric count.

Thickness

A compressometer having a presser foot, 1 inch in diameter was used. The foot was gradually lowered and pressure gradually increased to 0.05 pounds per square inch. The thickness was read to the nearest 0.001 of an inch after a 10 second interval. Four measurements were taken on each fabric treated alike and were averaged to obtain the thickness value for each treatment and fabric.

Weight

Pieces 2 inches square were cut with a die from the washed samples as well as from the original fabric. These were weighed on a 5 gram Roller-Smith precision balance to the nearest 0.001 of a gram. The mean values of the four readings for the new fabric and the four readings for each of the treated samples were converted to ounces per square yard.

Yarn Number

Forty yarns, 10 centimeters in length, were cut from each sample of new fabric. To assure accuracy in cutting samples, the yarn was carefully raveled and measured on the Suter Twist testing device under tension of 0.25 grams per tex. Each yarn was weighed in milligrams on a Universal yarn numbering balance. The mean values for each fabric were converted to grams and reported as tex units (32).

Fabric Strength and Elongation

Strength and elongation measurements were made on samples cut $1\frac{1}{2}$ inches wide by 7 inches long and raveled to a width of 1 inch by removing approximately the same number of lengthwise yarns from each side. Breaks were made on four dry samples and four wet samples for each swatch of fabric. These samples included new and treated swatches.

The pendulum type, motor driven, breaking strength machine equipped with an autographic recorder was used, operating with a uniform speed of 12 inches $\pm \frac{1}{2}$ inch per minute. The load capacity used was 150 pounds.

The faces of the clamps used on the machine measured 1 by 2 inches and the distance between the clamps at the beginning was exactly 3 inches. An initial load of 6 ounces was placed on the sample to assure uniform tension and to align the sample before tightening the lower clamp.

The mean values of treatments and fabrics were recorded in pounds as the breaking strength of the fabric.

The elongation of the fabric under stress was obtained by means of an autographic recording device on the breaking strength machine. Readings were recorded to the nearest 0.01 of an inch and calculated from the point indicating the first application of stress to the point indicating the break. The mean of the determinations in the warp and the filling was reported in per cent elongation.

Four samples of each of the fabrics were measured. Two of these were warp samples and two were filling. An average was taken of the replicates so that there was only one value for each treatment which was the mean of four readings. The original fabric was also cut into two replicates and two sets of samples so that the readings of the original fabric would also be a mean of four readings.

Fluorescence

Fluorescent brighteners are being used on white materials to improve their apparent whiteness (29). An ultraviolet lamp was used to detect the presence of fluorescent finishes on the fabrics and brighteners in the washing products. No measurement was recorded. Each sample, new and treated, was placed under the light of the ultra-violet lamp in a completely dark room. The cotton, nylon and the blend fluoresced and so indicated the presence of brighteners in the finish of the new fabrics. The Dacron did not show fluorescence.

At each of the intervals, when the materials were measured for whiteness retention and reflectance, they were examined again to check on the presence or absence of fluorescent brighteners. This repeated checking was to determine if any appreciable change were taking place on the samples, especially the non-fluorescing Dacron.

Dimensional Stability

All of these fabrics were measured for dimensional stability. The 20 inch squares were marked with hand stitching of white thread and three measurements were made in the warp direction and three in the filling direction. Measurement of these markings on each of the washed samples was made at the end of the first, tenth, twentieth and thirtieth washings. An average of the three measurements in each direction was reported as dimensional stability for that sample at each interval.

Reflectance and Whiteness Retention

The Gardiner Multipurpose Reflectometer was used to make the reflectance and whiteness retention readings.

> This machine is a high precision, null balance type instrument used for measuring reflectance, color, gloss, transmission and haze. A light-balancing, or Multipurpose type circuit is used for the measurement of reflectance and color.....Light from a single incandescent source is directed along two paths; one to the comparison photocell, and the other, after reflection from the sample, to the test (measuring) photocell. The position of the currents produced by the two cells are equal.....Readings are taken from the proper scale on the rotating drum.[4]

All measurements with this instrument are comparisons with a standard. In this experimental work, the standard was vitreous enamel having reflectance of 89.9 per cent with the green filter, 90.6 per cent with the amber filter and 83.5 per cent with the blue filter.

The samples were folded to six thicknesses and backed by the control tile when inserted into the instrument. The corners marking the dimensional stability square were used in order to assure that the readings were taken on approximately the same area throughout the study. Warp and filling readings were taken by inserting the material with warp threads in a horizontal line and the material then turned at right angles for the filling reading. Greater accuracy in measurement was assured by rereading the sample of each fabric giving a total of four readings for each direction. The mean of these readings is reported for each direction.

The machine after a 10 minute warm-up period was

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[4]<u>Instruction Manual</u>, <u>The Automatic Multipurpose Reflectometer</u>. Gardner Laboratory Inc. Bethesda, Maryland. p.1.

regulated for reading with the green filter, the samples of each fabric were read and readings recorded. The fabrics were then read with the amber and blue filters in the same manner. Then the whiteness retention factor for each sample was calculated by substituting the readings in the following formula:

$$\text{Whiteness Retention} = \frac{A - B}{G}$$

The samples were measured following the first, tenth, twentieth and thirtieth washings, as well as in the original state.

<u>Statistical Evaluation</u>

The data collected in this study have been submitted to statistical analyses using the analysis of variance techniques (34) and Duncan's Multiple Range Test (4). The design of the experiment was a completely randomized plan with a factorial arrangement of treatments consisting of four materials, four treatments, five washings and two directions, in replicate.

An analysis of variance was conducted for both the reflectance readings and the whiteness retention factors. The readings using the green filter were reported as reflectance readings. The whiteness retention factors were calculated by formula from readings with the green, amber and blue filters. These values were used in each analysis of variance.

The multiple range test was used to evaluate further the significance of differences between specific mean values.

DATA AND DISCUSSION

To simplify the discussion of data, reference to experimental work is identified by code: samples laundered with hard water and syndet, <u>HSy</u>; those laundered with hard water, softener and soap, <u>HSSo</u>; those laundered with softened water and syndet, <u>SSy</u>; and those laundered with softened water and soap, <u>SSo</u>.

<u>Fabric Count</u>

The warp count of the cotton sample was 140 while the filling yarns averaged only 57. The counts of the Dacron, nylon and the blended fabric were similar to each other in both directions. The differences between the warp and filling count of the Dacron and nylon fabrics varied from 32 to 44 yarns whereas there was a difference of 83 yarns per inch for the all-cotton fabric. (See Table 1)

<u>Thickness</u>

The original samples of both the cotton and the blended fabric measured 0.008 of an inch in thickness. After 30 washings the cotton samples <u>HSy</u> and <u>SSy</u> measured 0.011 of an inch and samples <u>HSSo</u> and <u>SSo</u> were 0.012 of an inch in thickness. The Dacron-cotton blend increased one thousandth of an inch with treatments <u>HSy</u>, <u>SSy</u> and <u>SSo</u> and two thousandths of an inch with the <u>HSSo</u>. (See Table 2)

Table 1. Fabric Count and Yarn Number of Original Materials

Fabric	Fabric count Threads per inch Warp	 Filling	Yarn number Tex number Warp	 Filling
Cotton	140	57	13.83	13.13
Dacron-cotton blend	118	74	15.28	10.40
Dacron	104	71	8.20	8.20
Nylon	102	70	8.45	8.55

Table 2. Fabric Thickness and Weight of Original Materials and Samples Laundered 30 Times

Treat-ment	Thickness 0.001 of an inch				Weight Ounces per square yard			
	Cotton	Blend	Dacron	Nylon	Cotton	Blend	Dacron	Nylon
New	0.008	0.008	0.004	0.004	3.35	3.32	1.052	1.006
HSy	0.011	0.009	0.004	0.004	3.40	3.33	1.052	1.006
HSSo	0.012	0.010	0.004	0.004	3.38	3.34	1.052	1.006
SSy	0.011	0.009	0.004	0.004	3.40	3.34	1.052	1.006
SSo	0.012	0.009	0.004	0.004	3.42	3.32	1.052	1.006

There were no changes in the measurements of the Dacron and nylon samples from the original samples as compared to those washed 30 times. Nor was there any difference in the measurements for the different treatments (see Table 2).

The slight change in thickness can presumably be credited to the dimensional stability of the fabrics, as both the cotton and the blended fabrics did shrink from the original measure (see Figure 1). This shrinkage would cause warp and filling yarns to shorten and become larger in circumference.

Weight

There were no changes in weight measurements of the Dacron and nylon samples which were washed 30 times. The cotton and the blended fabric did show slight variations in weight when the treated samples are compared with the original fabrics.

All-cotton samples increased in weight after 30 washings, the increases varying from 0.03 to 0.07 ounces per square yard.

The Dacron-cotton blend also showed slight increases in weight for all treatments with the exception of SSo, which remained the same as the original.

Dimensional change could be responsible for the increased weight.

Yarn Number

The tex system was used for reporting yarn number. A tex unit is defined as the weight in grams of 1000 meters of yarn (32). The tex yarn numbering system is a direct one, in which yarn numbers increase with an increase in size of the yarn.

The fabrics woven of only one fiber have approximately the same tex in both directions (see Table 1). The Dacron-cotton blended fabric had a warp yarn nearly one third larger than its filling yarn.

Fabric Strength and Elongation

Another measure of fabric properties is breaking strength. These measurements were made before and after treatments and in both dry and wet states (see Table 3).

Although no statistical analyses were made of these data, it can be seen that, in general, a specific treatment did not have a decisive effect on these fabrics. All of the cotton, Dacron and blended samples tended to be stronger wet than when dry, and this was true in both directions. The reverse was true of the nylon samples.

Elongation represents the amount of stretch before breaking. This is reported in per cent (see Table 4). After treatment the elongation values differed from the new, some being higher and some lower. However, the fabrics con-

Table 3. Fabric Strength of Original Materials and Samples Washed 30 Times Using Four Different Treatments

Fabric	Treatment	Warp		Filling	
		Dry Pounds	Wet Pounds	Dry Pounds	Wet Pounds
Cotton	New	66.6	77.5	24.0	32.5
	HSy	67.5	82.6	32.4	33.6
	HSSo	63.2	77.1	31.0	32.6
	SSy	72.0	75.9	33.4	36.2
	SSo	65.1	70.4	25.9	31.9
Dacron-cotton	New	72.9	76.9	26.8	28.0
	HSy	73.5	74.9	28.4	26.4
	HSSo	74.1	76.1	27.2	27.8
	SSy	74.9	74.9	26.2	25.6
	SSo	70.4	76.0	24.8	26.9
Dacron	New	70.1	73.6	51.8	52.2
	HSy	71.5	68.1	46.9	52.0
	HSSo	71.1	69.0	51.4	48.6
	SSy	68.5	70.9	51.5	48.2
	SSo	68.8	70.3	49.0	49.2
Nylon	New	91.0	71.0	62.4	49.4
	HSy	89.6	72.2	60.5	52.1
	HSSo	89.2	74.4	61.9	49.6
	SSy	89.2	75.0	62.2	48.5
	SSo	88.4	75.4	58.4	50.2

Table 4. Fabric Elongation of Original Materials and Samples Washed 30 Times Using Four Different Treatments

Fabric	Treat-ment	Warp		Filling	
		Dry Per cent	Wet Per cent	Dry Per cent	Wet Per cent
Cotton	New	11.67	15.83	9.17	13.33
	HSy	14.17	17.50	11.67	10.00
	HSSo	14.17	14.17	10.83	10.00
	SSy	13.33	15.00	10.00	12.50
	SSo	14.17	13.33	9.17	10.00
Dacron-cotton	New	26.67	25.83	21.67	20.00
	HSy	27.50	24.17	20.83	15.83
	HSSo	25.83	24.17	18.33	15.83
	SSy	25.83	25.00	19.17	17.50
	SSo	27.50	25.83	20.00	17.50
Dacron	New	27.50	28.33	28.33	24.17
	HSy	26.67	21.66	20.00	24.17
	HSSo	25.83	25.00	24.17	22.50
	SSy	24.17	25.83	24.17	20.00
	SSo	25.00	25.00	25.83	23.33
Nylon	New	28.33	27.50	33.33	30.00
	HSy	28.33	28.33	30.00	30.83
	HSSo	29.17	29.17	30.00	26.67
	SSy	28.33	28.33	30.00	29.17
	SSo	30.00	31.67	29.17	31.67

taining Dacron showed a tendency to lose elongation after all types of treatments.

Fluorescence

When examining the fabrics under the ultra-violet lamp, no change in appearance could be observed until the twentieth washing. The cotton samples washed in the syndet, in either type of water, then showed marked loss of fluorescence. The Dacron-cotton blend exhibited a loss of fluorescence in all samples but it was most marked in the HSy sample. Although all of the nylon samples showed some loss nylon samples subjected to syndet treatments showed greatest loss of fluorescence. The Dacron had not shown fluorescence in the original fabric and it did not appear to attract the fluorescent substances from the washing products. This was characteristic of the Dacron studied by Furry and others in their work with fluorescent brighteners (7).

The whiteners in the soap used in laundering seemed to keep the fabrics brighter than those in the syndet. However, it has been reported that brighteners used in laundry products can cancel out the effectiveness of brighteners in the fabric and this could have occurred since both products and samples contained unidentified brighteners (22).

Dimensional Stability

The greatest loss in dimensional stability for all of the fabrics was in the warp direction (see Appendix Table 1). The type of treatment did not seem to be a factor in the loss of stability. In the warp direction all fabrics, except Dacron, showed shrinkage after the initial washing (Figure 1). Additional shrinkage took place in all fabrics with successive washings including the Dacron samples. There were no statistical analyses of these data.

Reflectance and Whiteness Retention

Reflectance measurements were made on all of the fabrics. These measurements, taken with the green filter in the reflectometer are comparable to the vision of the human eye. The reflectance readings did not vary greatly for any fabric, treatment or interval (see Table 5). An analysis of variance indicated there were no significant differences among these readings (see Appendix Table 2).

Whiteness retention was calculated from readings using the green, amber and blue filters. Each of these readings are a percentage of a possible 100 per cent. These calculations of whiteness are on a blue to yellow scale. A retention factor that is negative indicates a blue white; zero a true white; and a positive factor indicates discoloration (yellowness). Retention factors of

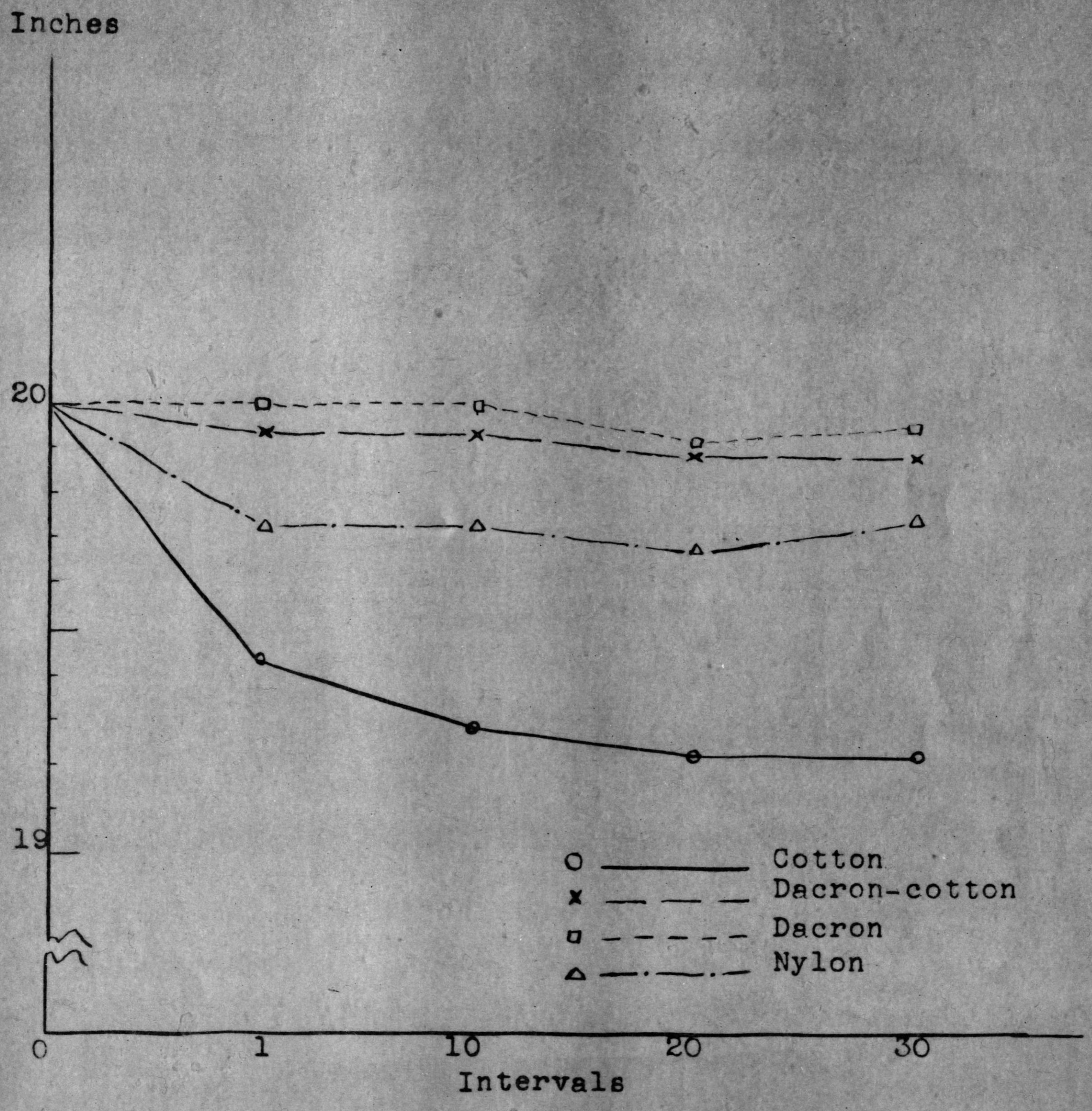

Figure 1. Dimensional stability of fabrics in the warp direction after the four washing intervals

Table 5. Reflectance Measurements of Fabrics When New and After Each Laundering Interval Using Four Different Treatments

Fabric	Treatment	Laundering Intervals				
		0	1	10	20	30
Cotton	HSy	88.0	87.2	87.9	87.4	86.8
	HSSo	88.3	87.6	87.5	86.5	87.6
	SSy	88.6	87.7	87.8	88.5	88.3
	SSo	88.2	87.8	87.9	89.1	88.7
Dacron-cotton	HSy	85.6	85.9	87.9	86.1	85.6
	HSSo	85.5	85.9	88.7	85.9	85.6
	SSy	85.6	85.7	88.5	87.1	87.0
	SSo	85.4	85.5	88.5	86.1	86.1
Dacron	HSy	88.4	88.6	88.3	88.4	87.8
	HSSo	88.8	88.5	88.3	88.3	88.1
	SSy	88.5	88.8	88.7	88.5	88.5
	SSo	88.4	89.0	88.6	88.5	88.3
Nylon	HSy	89.9	88.6	87.9	87.9	87.3
	HSSo	89.9	89.3	88.7	88.2	87.8
	SSy	90.0	88.8	88.5	88.9	88.4
	SSo	89.6	89.2	88.5	88.5	88.0

zero are not common.

Calculations for whiteness retention factors showed considerable variation (see Appendix Table 3). Differences between fabrics and laundry intervals were statistically significant, whereas any differences occurring between treatments and in direction were not statistically significant (see Appendix Table 4).

All of these fabrics were purchased as white. However, visual inspection seemed to show differences in degrees of whiteness (see swatches in Appendix, Exhibit I). Examination of data in Appendix Table 3 shows negative values for the cotton fabrics when new. All other values are positive, indicating varying degrees of yellowness in the original fabric. These factors varied from -1.02 for the cotton to a +3.09 for nylon. This meant that the cotton samples were a bluish white, the blended fabric had a slight yellowness and both of the all-synthetic fabrics showed yellowness before laboratory treatment began. This difference continued to be present in the fabrics and was generally progressive through 30 launderings (see Figure 2). A comparison of the new material with laundered materials showed increased yellowness for all except Dacron which changed only slightly.

The mean values of the two significant variates, materials and laundering intervals, were then evaluated by Duncan's Multiple Range Test. The test showed that there

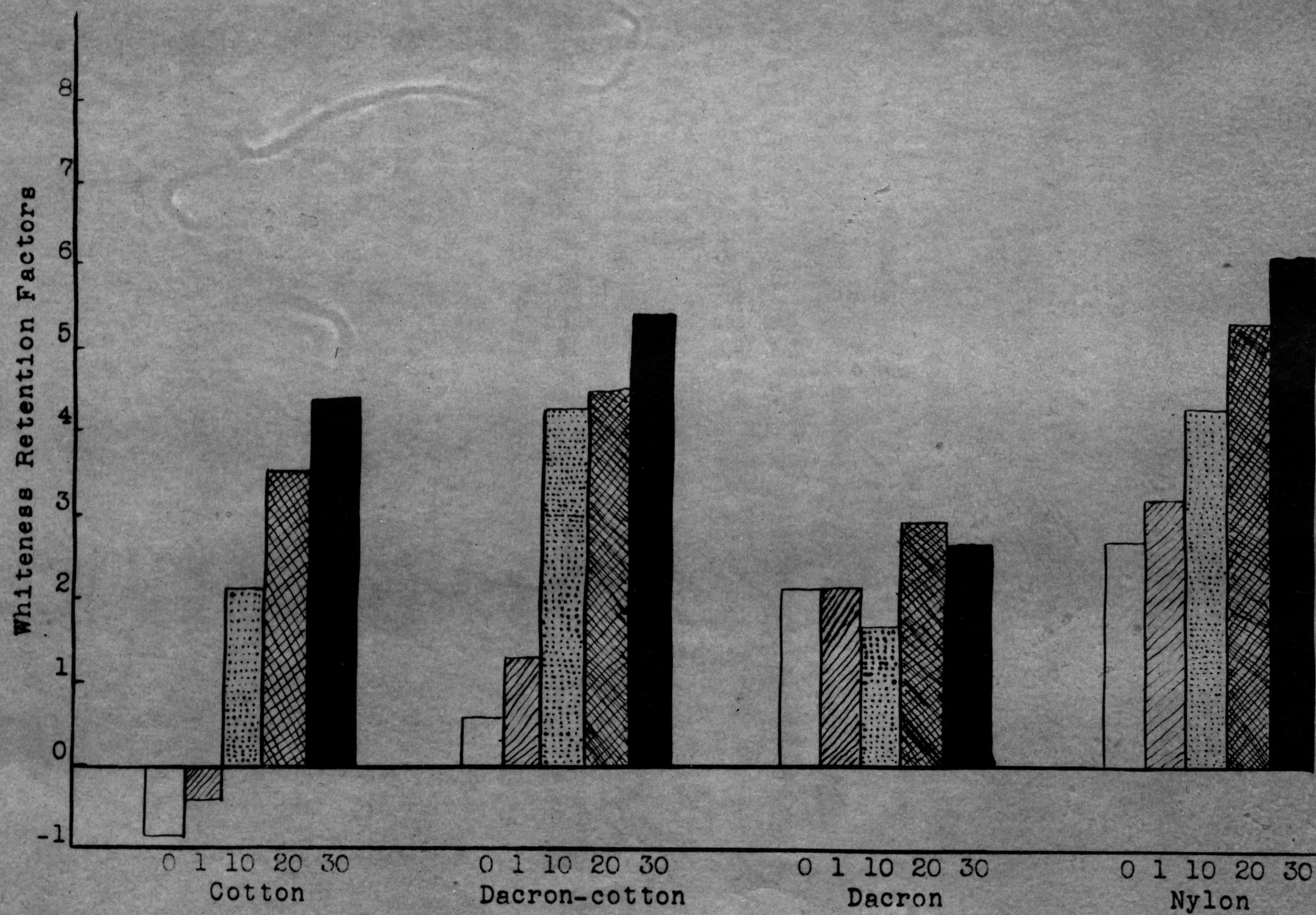

Figure 2. Comparison of whiteness retention factors for samples after each of five laundering intervals

was a significant difference between the whiteness retention factors of the nylon and cotton fabrics and between the nylon and Dacron fabrics (see Appendix Table 5). This difference was significant at the 1 per cent level of probability.

For the laundering intervals, there was a significant difference at the 1 per cent level of probability between all of the original fabrics and the samples that had been laundered 20 times. This was also true of the samples when laundered 30 times and compared to the original fabrics. Washing these samples once made some change from the original but no significant differences appeared until the tenth interval and this difference was significant only at the 5 per cent level of probability. The difference between readings of the twentieth and thirtieth washings did not change enough to be statistically significant. When a fabric has become yellowed this tendency may continue through repeated laundering but the rate is not necessarily constant. Other workers have found this to be true also (7).

Since the treatments used in this study did not cause significant differences, it might be concluded that any of the treatments themselves would not alter whiteness retention factors.

CONCLUSIONS

The objectives of this study were to determine 1) if white fabrics, especially those man-made fibers that have caused consumer dissatisfaction, would discolor when the recommended laundry practices were followed and soil was not involved, and 2) if several combinations of washing products were used would any combination produce whiter results in any of the fabrics used in the experimental washings. Within the limits of this study the following general conclusions might be drawn:

1. All four of the fabrics yellowed with continued laundering when soil was not involved.
2. Four different treatments were used but results showed no significant differences among them.

Although no mechanical measurements of fluorescence were made, it was observed that the fabrics treated with syndet appeared to lose fluorescence. Dacron, which showed no fluorescence, did not give evidence of picking up fluorescence from the detergents.

SUMMARY

Four nearly white fabrics were chosen for a laundering study of the retention of original whiteness by certain fibers using methods simulating hand laundry. A cotton fabric was selected as the control and the experimental fabrics were made of Dacron, nylon and a 65-35 per cent blend of Dacron and cotton. Methods were planned so as to assure a uniform treatment of each sample. White washing products, recommended as appropriate for this type of work, were chosen for this study. Nine samples were cut from each fabric. One was retained as the original sample and the remaining eight were washed. Four samples were used as replicate A and four as replicate B. There were four treatments used: 1) hard water with syndet; 2) hard water, soap and softener; 3) softened water and syndet; and 4) softened water and soap. The samples were washed 30 times, measuring at intervals of 1, 10 20 and 30 washings. Physical property measurements such as, fabric count, weight, thickness, yarn number, fabric strength and elongation, fluorescence and dimensional stability were made on these samples. Reflectance and whiteness retention were measured with the Gardiner Multipurpose Reflectometer. The results were evaluated statistically by a simple analysis of variance and Duncan's Multiple Range Test. Only differences in whiteness retention among materials and the number of washings were statis-

tically significant at the 1 per cent level of probability. The multiple range test indicated that when comparing the cotton and nylon, and also the Dacron and nylon, they were significantly different. The significant differences for the number of times the samples were washed began to appear at the tenth washing and were highly significant at 20 washings. It would seem that the methods, procedures and products used in laundering does not prevent yellowing of these fabrics. It might be recommended that the best procedure is to follow the advice of the manufacturers of the fiber, fabric or garment concerning laundering methods.

SUGGESTIONS FOR FURTHER STUDY

1. Study of reclamation of white Dacron, nylon and blended fabric after they have been yellowed as a results of laundering.
2. As the fabrics were observed during the course of the study, it appeared that the materials containing synthetic fibers showed a tendency to pick up and hold soil encountered in handling. A study could be made to determine whether the use of fabric softeners to reduce static electricity might contribute toward prevention of soiling.
3. This experiment could be repeated using distilled or naturally soft water and the results compared to determine whether any portion of the observed results were due to water rather than product.

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APPENDIX

Table 1. Dimensional Stability Measurements in Inches Taken at the Four Laundering Intervals and For Each Treatment In Both Directions on a 20 Inch Square

Fabric	Treatment	Laundering Intervals 1	10	20	30
Cotton					
warp	HSy	19.44	19.35	19.19	19.19
	HSSo	19.44	19.29	19.19	19.19
	SSy	19.44	19.28	19.25	19.25
	SSo	19.44	19.26	19.23	19.25
filling	HSy	20.00	20.00	20.00	20.00
	HSSo	20.00	20.00	20.00	20.00
	SSy	20.00	20.00	20.00	20.00
	SSo	20.00	20.00	20.00	20.00
Dacron-cotton blend					
warp	HSy	19.94	19.94	19.88	19.88
	HSSo	19.94	19.94	19.88	19.88
	SSy	19.94	19.94	19.88	19.88
	SSo	19.94	19.94	19.88	19.88
filling	HSy	19.94	19.94	19.88	20.00
	HSSo	19.95	19.94	19.88	20.00
	SSy	19.94	19.94	19.88	20.00
	SSo	19.94	19.94	19.88	20.00
Dacron					
warp	HSy	20.00	20.00	19.89	19.96
	HSSo	20.00	20.00	19.91	19.94
	SSy	20.00	20.00	19.91	19.94
	SSo	20.00	19.99	19.91	19.94
filling	HSy	20.00	20.00	20.00	20.00
	HSSo	20.00	20.00	20.00	20.00
	SSy	20.00	20.00	20.00	20.00
	SSo	20.00	20.00	20.00	20.00
Nylon					
warp	HSy	19.73	19.75	19.69	19.75
	HSSo	19.75	19.75	19.69	19.75
	SSy	19.73	19.75	19.69	19.75
	SSo	19.75	19.74	19.69	19.75
filling	HSy	19.88	19.88	19.88	20.00
	HSSo	19.88	19.88	19.88	20.00
	SSy	19.88	19.88	19.88	20.00
	SSo	19.88	19.88	19.88	20.00

Table 2. Analysis of Variance for Reflectance Measurements

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Total	319	28110.70	88.12	
Mat.	3	255.11	85.03	0.5164
Trt.	3	12.94	4.31	0.0026
Wash.	4	21.51	5.37	0.0033
Dir.	1	506.27	506.27	3.0745
Rep.	1	0.86	0.86	0.0005
MT	9	7.32	0.82	0.0005
MW	12	101.76	8.48	0.0515
MD	3	763.59	254.54	1.5457
TW	12	12.29	1.02	0.0062
TD	3	0.59	0.20	0.0012
WD	4	59.80	14.95	0.0908
MTW	36	13.48	0.37	0.0022
MTD	9	2.17	0.24	0.0015
MWD	12	163.43	13.62	0.0827
TWD	12	2.71	0.23	0.0014
MTWD	36	4.05	0.11	0.0007
Error	159	26182.82	164.67	

Table 3. Whiteness Retention Factors of Fabrics When New and After Each Laundering Interval and Four Different Treatments

Fabric	Treatment	Laundering Intervals				
		0	1	10	20	30
Cotton						
	HSy	-0.62	-0.23	1.48	3.89	4.90
	HSSo	-0.99	-0.29	1.45	3.68	5.48
	SSy	-1.02	-0.57	3.20	2.80	3.38
	SSo	-0.71	-0.37	2.19	3.54	3.81
Dacron-cotton						
	HSy	0.53	1.49	4.89	5.58	6.57
	HSSo	0.56	1.16	4.25	4.31	5.79
	SSy	0.41	1.29	4.04	3.85	4.40
	SSo	0.68	1.41	3.72	4.21	5.34
Dacron						
	HSy	2.03	1.74	1.90	3.01	3.11
	HSSo	2.01	2.24	2.05	2.72	3.08
	SSy	1.97	2.11	1.43	2.69	2.11
	SSo	2.33	2.22	1.59	3.42	2.41
Nylon						
	HSy	2.85	2.90	4.89	6.67	6.99
	HSSo	2.37	3.00	4.22	4.85	5.94
	SSy	2.47	3.32	4.04	5.35	5.55
	SSo	3.09	3.18	3.72	4.79	6.36

Table 4. Analysis of Variance for Whiteness Retention Factors

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Total	319	3933.1612	12.3297	
Mat.	3	271.0366	90.3455	5.0309**
Trt.	3	13.0119	4.3373	0.2415
Wash	4	560.8700	140.2175	7.8080**
Dir.	1	0.0296	0.0296	0.0016
Rep.	1	1.1940	1.1940	0.0065
MT	9	8.0165	0.8907	0.0496
MW	12	149.1295	12.4275	0.6920
MD	3	11.4455	3.8151	0.2124
TW	12	25.5221	2.1268	0.1184
TD	3	0.5169	0.1723	0.0096
WD	4	1.9338	0.4844	0.2691
MTW	36	20.4705	0.5686	0.3166
MTD	9	1.0482	0.1164	0.0065
MWD	12	2.8882	0.2407	0.0134
TWD	12	1.5374	0.1281	0.0071
MTWD	36	9.1559	0.2543	0.0142
Error	159	2855.3546	17.9582	

** Significant at 1 per cent level of Probability.

Table 5. Multiple Range Test for Whiteness Retention Factors of Materials

Varietial Means Ranked in Order

Cotton	Dacron	Dacron-cotton	Nylon
1.98	2.31	3.22	4.35

Standard Error of a Varietial Mean[1]

$$Sm = \sqrt{17.9582/80} = .473 \quad (N_2 = 159)$$

Shortest Significant Ranges (Taken from Standard Table)

5 Per Cent Level of Probability

	(2)	(3)	(4)
p	2.77	2.92	3.02
Smp	1.31	1.38	1.43

1 Per Cent Level of Probability

p	3.64	3.80	3.90
Smp	1.72	1.80	1.84

Nylon - Cotton	2.37**
Nylon - Dacron	2.04**
Nylon - Dacron/cotton	1.13
Dacron/cotton - Cotton	1.24
Dacron/cotton - Dacron	0.91
Dacron - Cotton	0.33

[1]Standard Error information obtained from Appendix Table 4
** Significant at the 1 per cent level of probability

Table 6. Multiple Range Test for Whiteness Retention Factors of Laundering Intervals

Varietal Means Ranked in Order

0	1	10	20	30
1.329	1.631	3.061	4.116	4.690

Standard Error of a Varietal Mean[1]

$Sm = \sqrt{17.9582/64} = .529 \quad (N_2 = 159)$

Shortest Significant Ranges (Taken from Standard Table)

5 Per Cent Level of Probability

	(2)	(3)	(4)	(5)
p	2.77	2.92	3.02	3.09
Smp	1.47	1.55	1.60	1.64

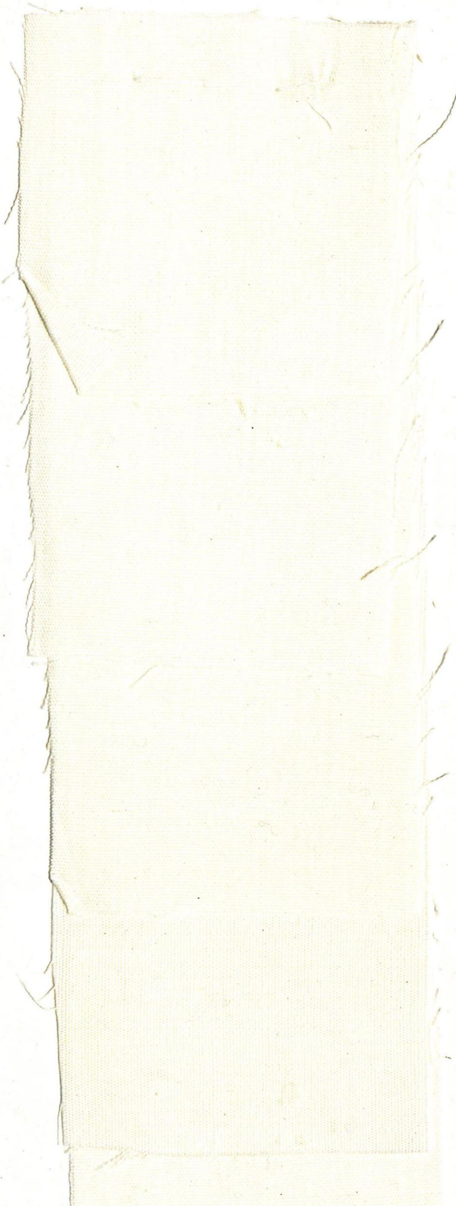
1 Per Cent Level of Probability

p	3.64	3.80	3.90	3.98
Smp	1.93	2.01	2.06	2.11

30 - 0	3.36**
30 - 1	3.06**
30 - 10	1.63*
30 - 20	0.58
20 - 0	2.79**
20 - 1	2.49**
20 - 10	1.06
10 - 0	1.73*
10 - 1	1.43
1 - 0	0.30

[1]Standard Error information obtained from Appendix Table 4
**Significant at the 1 per cent level of probability
* Significant at the 5 per cent level of probability

Exhibit I. Swatches of Original Cotton and Dacron-cotton Fabric and Samples Laundered 1, 10, 20 and 30 Times



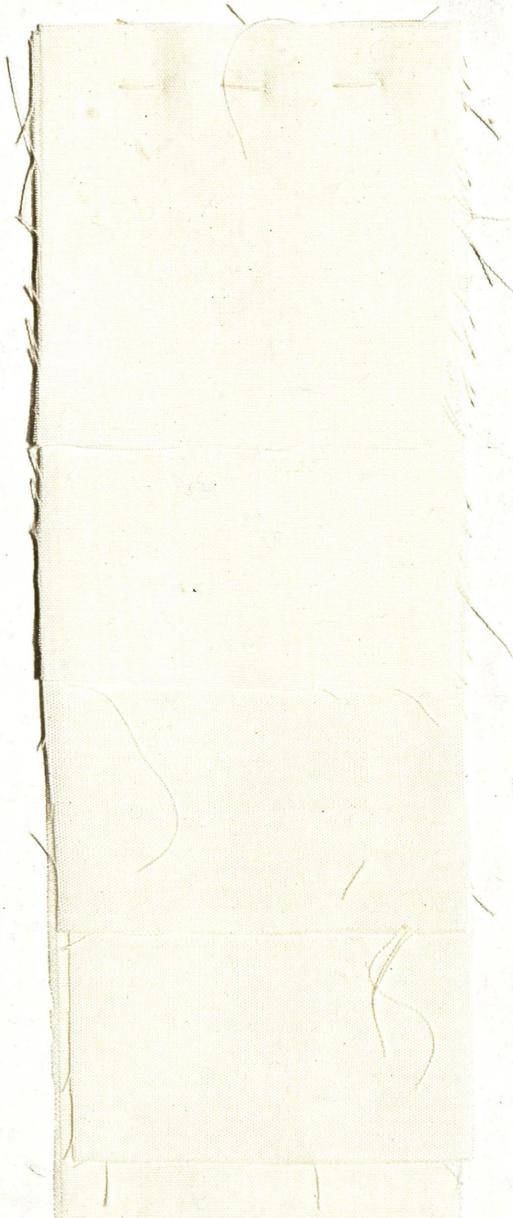
New

Once

10 Times

20 Times

30 Times



Cotton

Dacron-cotton

Exhibit II. Swatches of Original Dacron and Nylon Fabric and Samples Laundered 1, 10, 20 and 30 Times

New

Once

10 Times

20 Times

30 Times

Dacron

Nylon